Harnessing Interplanetary Scintillation with the MWA

Imaging without the needless details

John Morgan (ICRAR/Curtin)

Rajan Chhetri (ICRAR/Curtin)

Jean-Pierre Macquart
(ICRAR/Curtin)

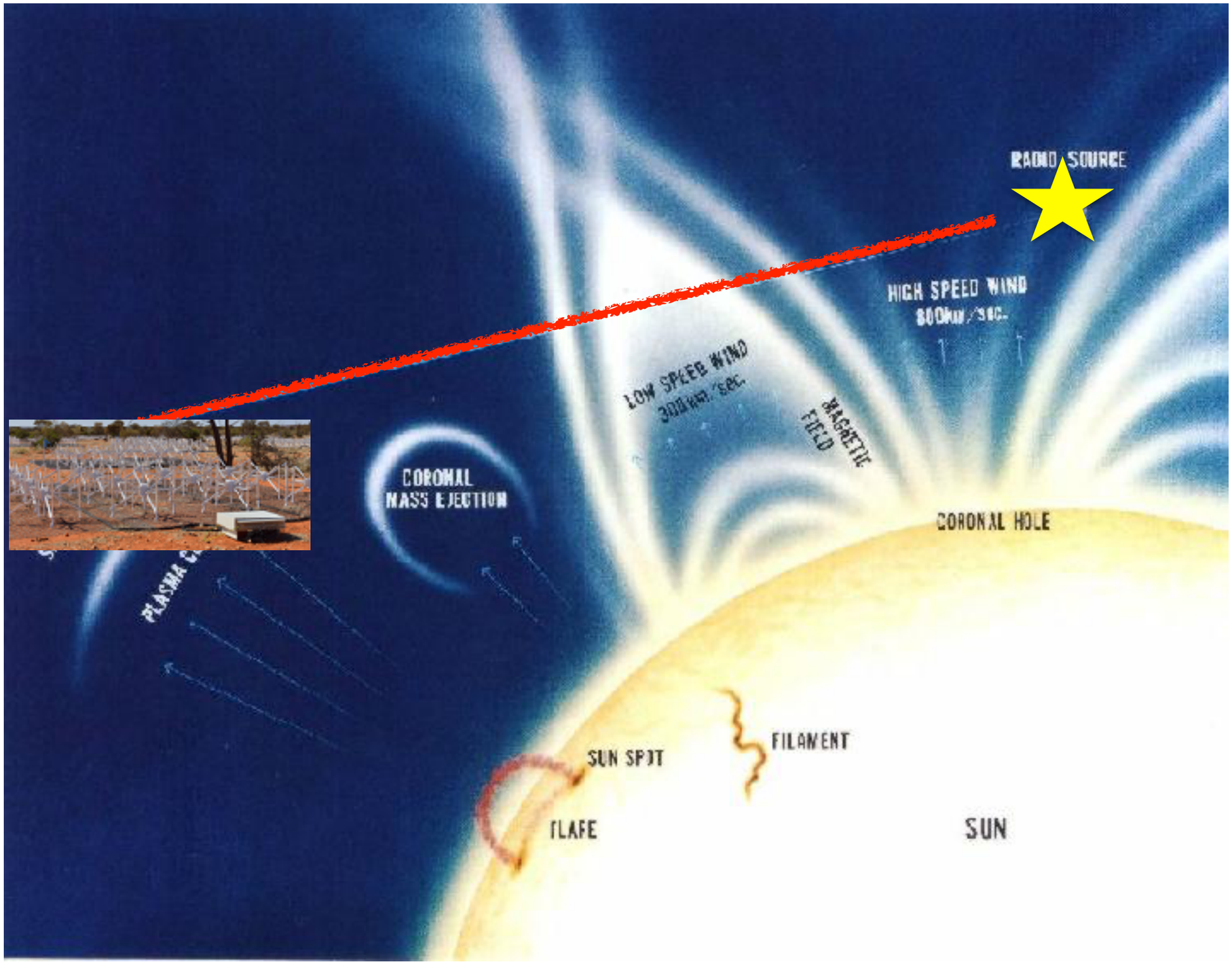
Ron Ekers (CASS/Curtin)

Elaine Sadler (USyd)

Marcello Giroletti (INAF)

Joe Callingham (ASTRON)

IPS is low-frequency VLBI for the masses!



Caused by density fluctuations in the solar wind

Temporal variations caused by random refraction crossing at ~400 km/s

Sensitive to angular scales ~0.3” at 150 MHz

Like having a 400km interferometer that forms fringes for you!

IPS nearly discovered pulsars

Hewish & Okoye 1965:

"The scintillation technique [showed] ... which radio sources had angular sizes in the range 0".1- 1".0. The first really unusual source ... turned up in 1965 when, with my student Okoye, I was studying radio emission from the Crab Nebula. We found a prominent scintillating component ... far too small to be explained by conventional synchrotron radiation and we suggested that this might be the remains of the original star which had exploded .... This source later turned out to be none other than the famous Crab Nebula Pulsar."
— Hewish, Nobel lecture

Image courtesy of NRAO/AUI and M. Bietenholz

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Widefield IPS with the MWA

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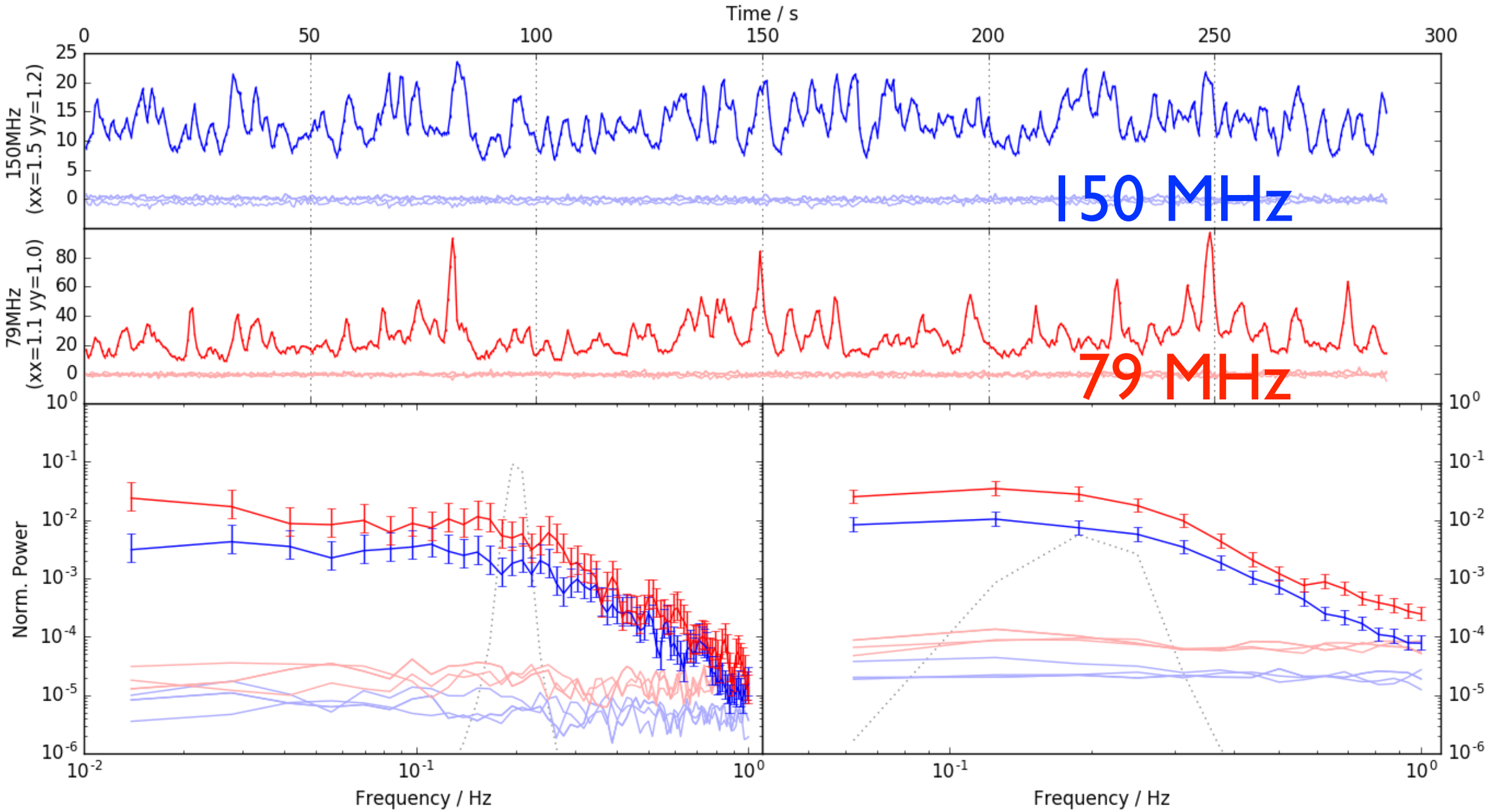
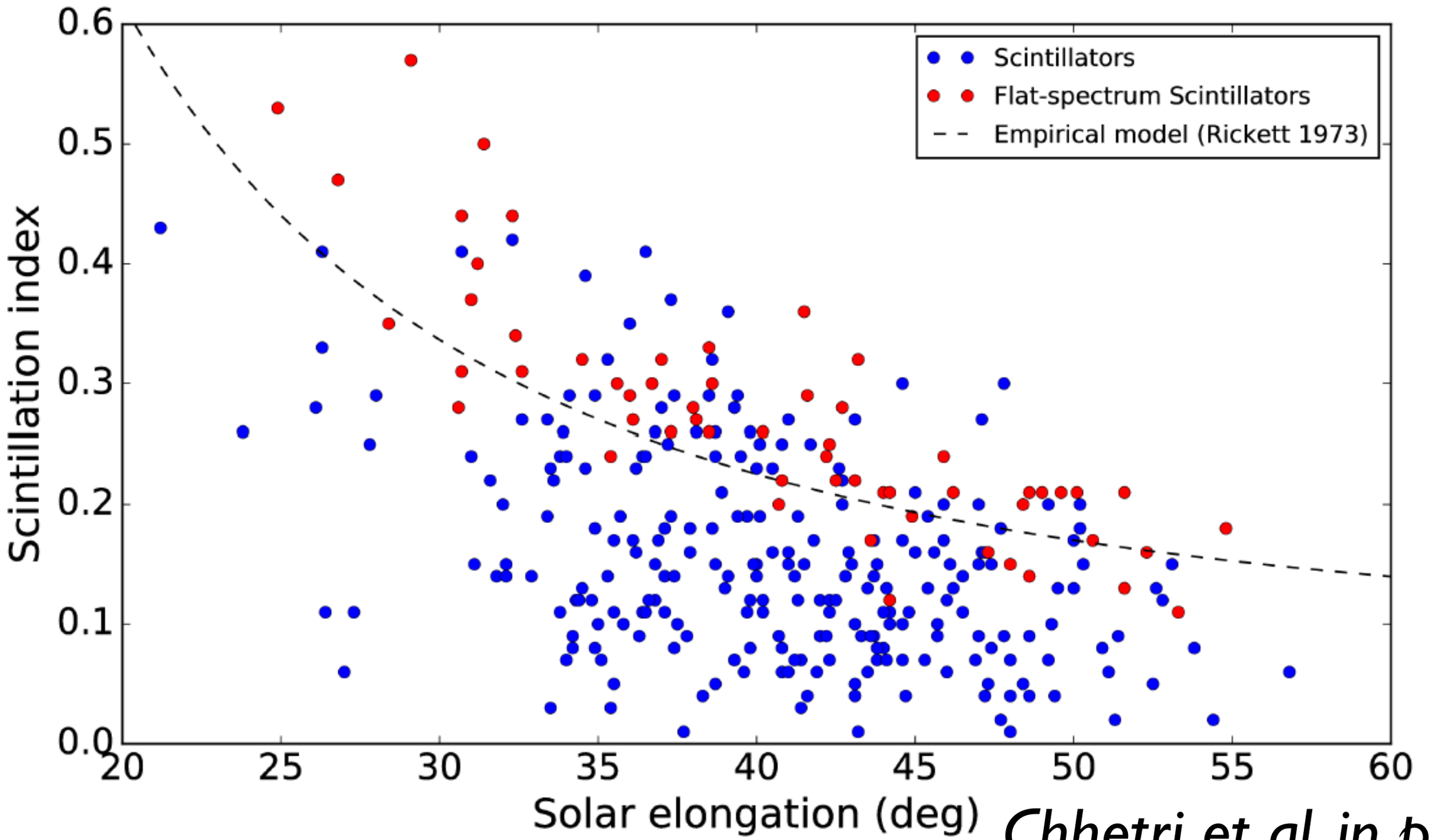
Widefield IPS with the MWA

An example

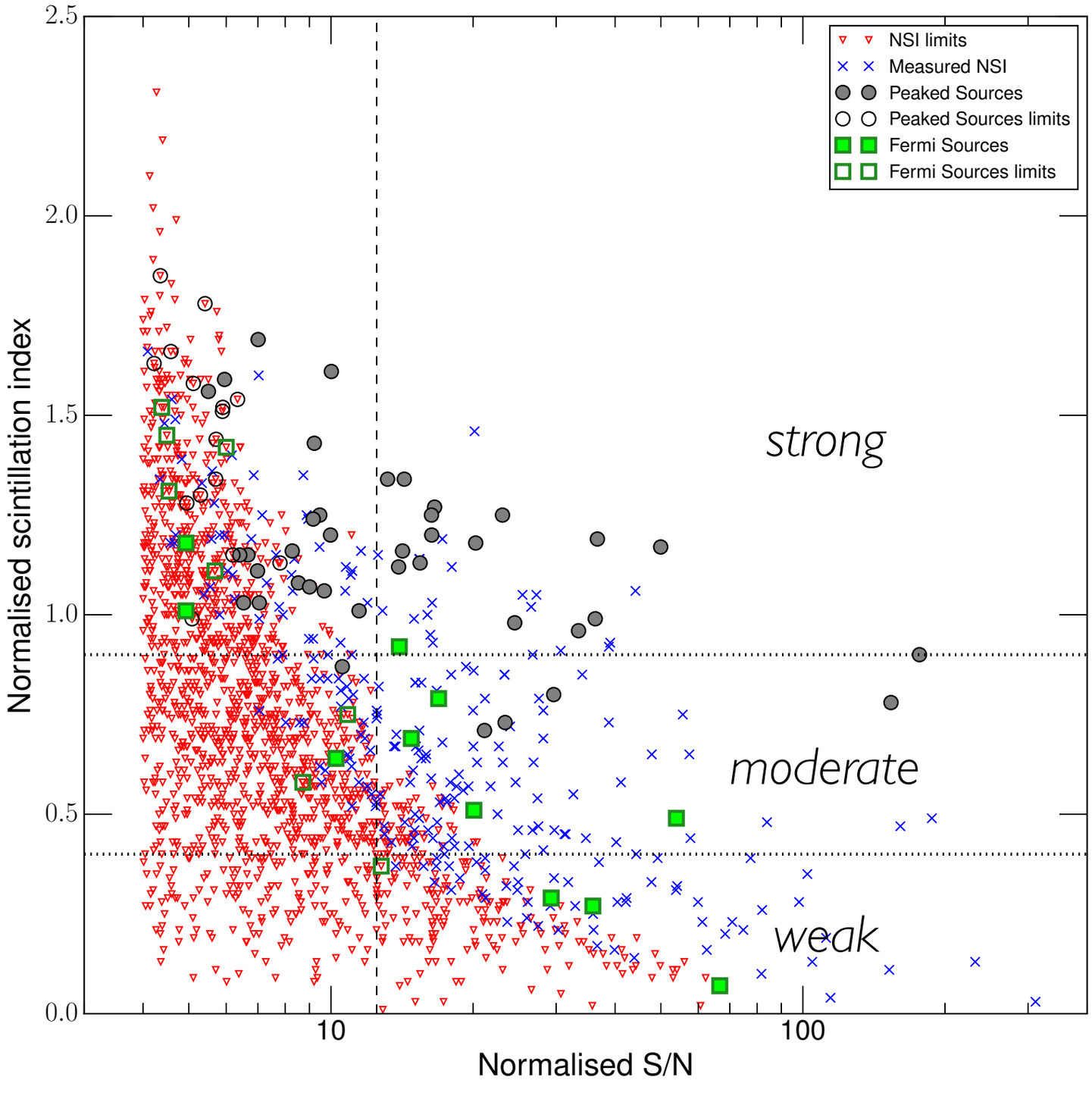

Time / s
0
50
100
150
200
250
300
150MHz
(xx=1.5 yy=1.2)
25
20
15
10
5
0
150 MHz
79MHz
(xx=1.1 yy=1.0)
80
60
40
20
0
79 MHz
Norm. Power
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Frequency / Hz
Frequency / Hz

Scintillation index with solar elongation



Chhetri et al. in press

What sources show IPS?



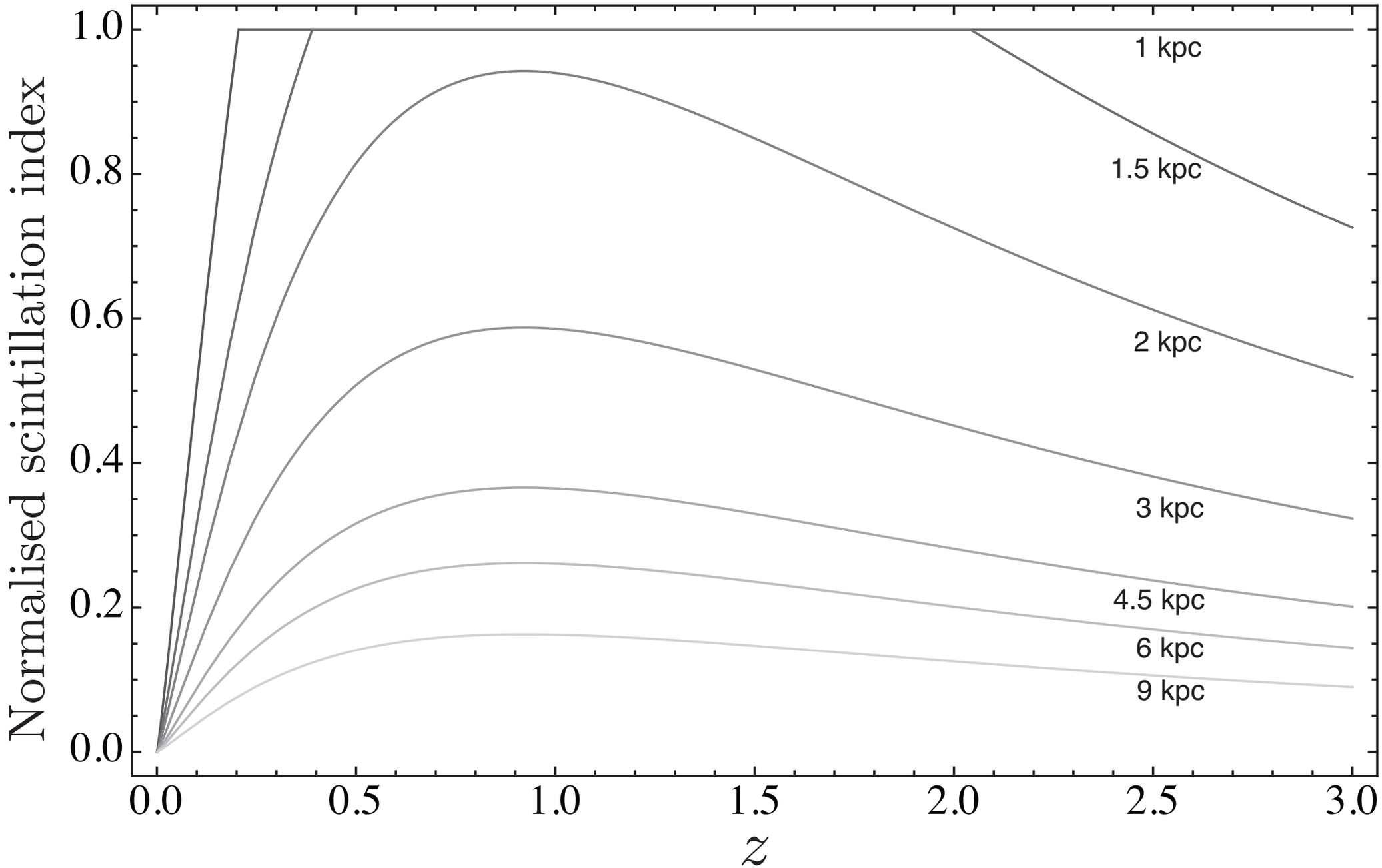
High S/N: 414 objects

- **Strong Scintillators**
  (NSI ≥ 0.9)
  9%

- **Moderate Scintillators**
  (0.4 ≤ NSI < 0.9)
  23%

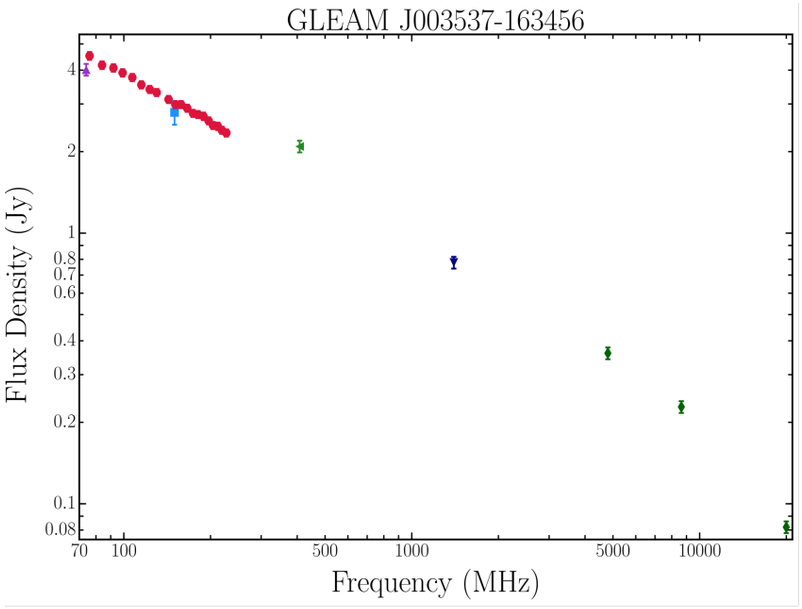
- **Weak/non Scintillators**
  (NSI < 0.4)
  53%

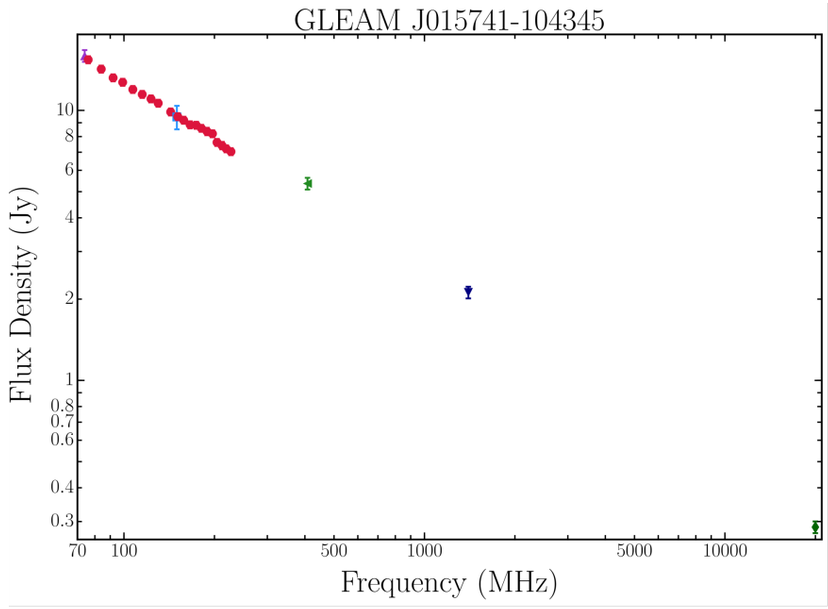
What sources show IPS?

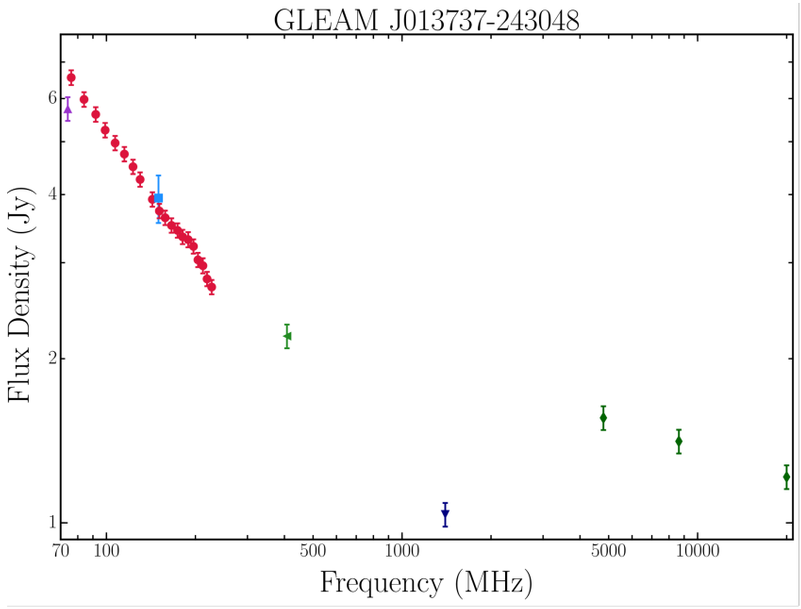


Which sources are compact?

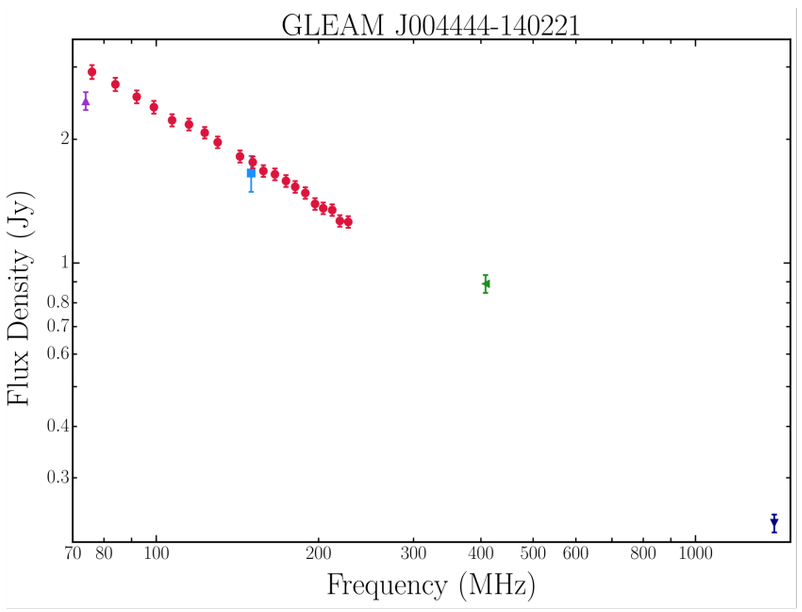
Weak Scintillators

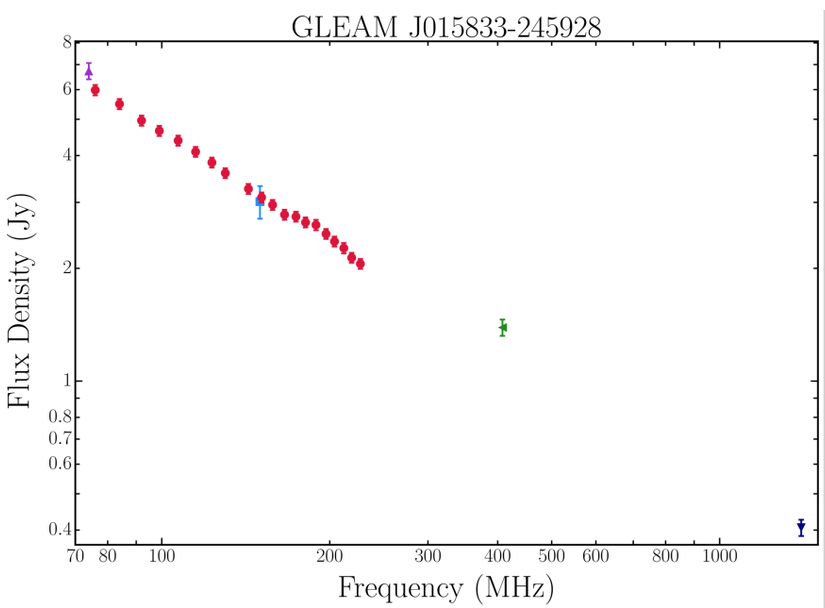


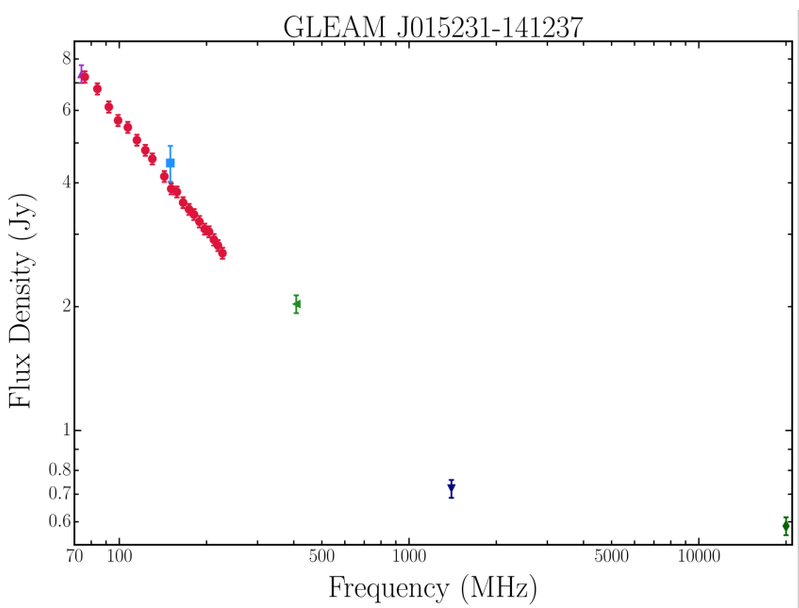




Moderate Scintillators



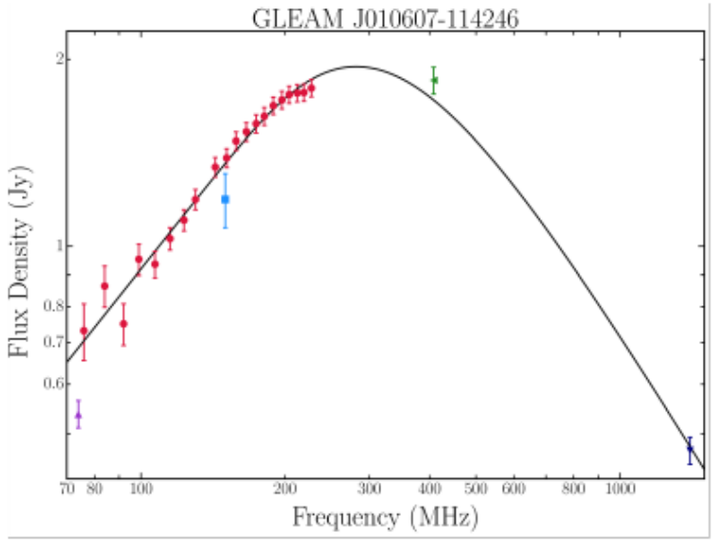


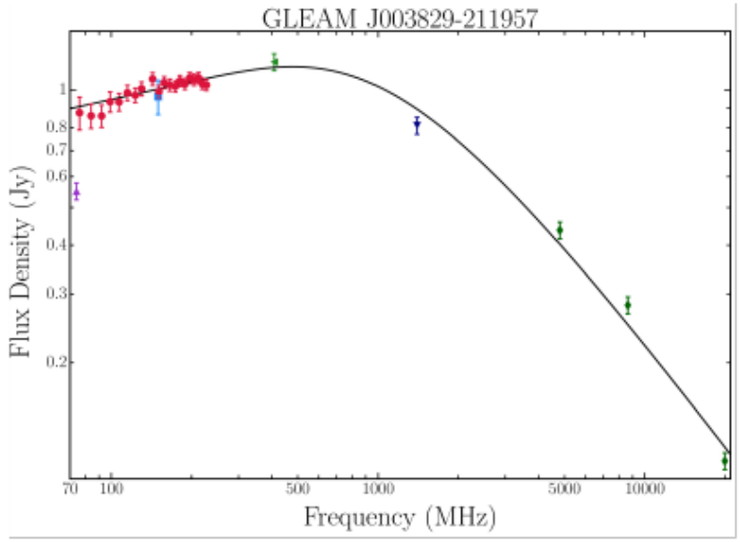


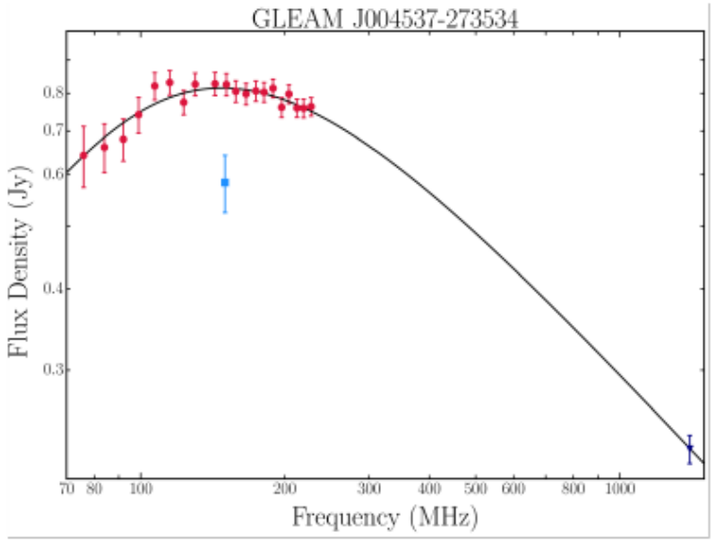
IPS with the MWA

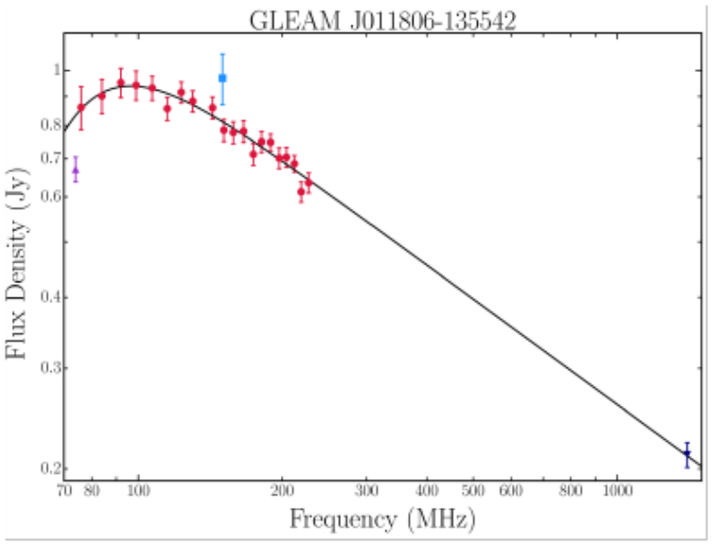
Peaked spectrum sources are all compact

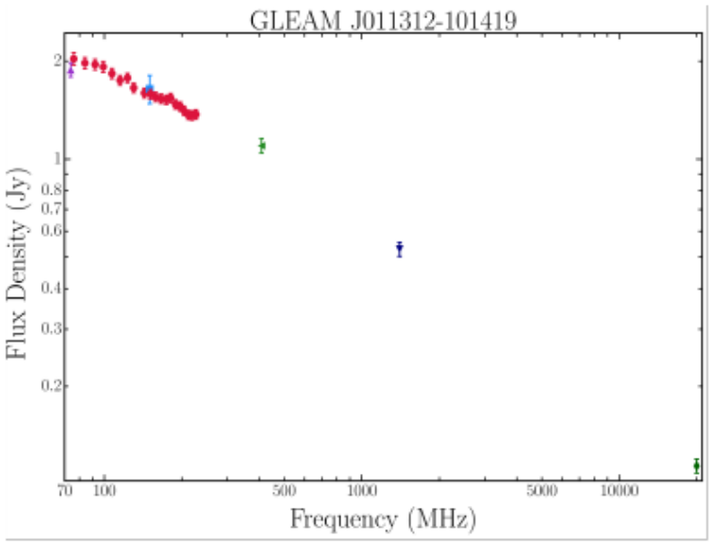
Strong Scintillators

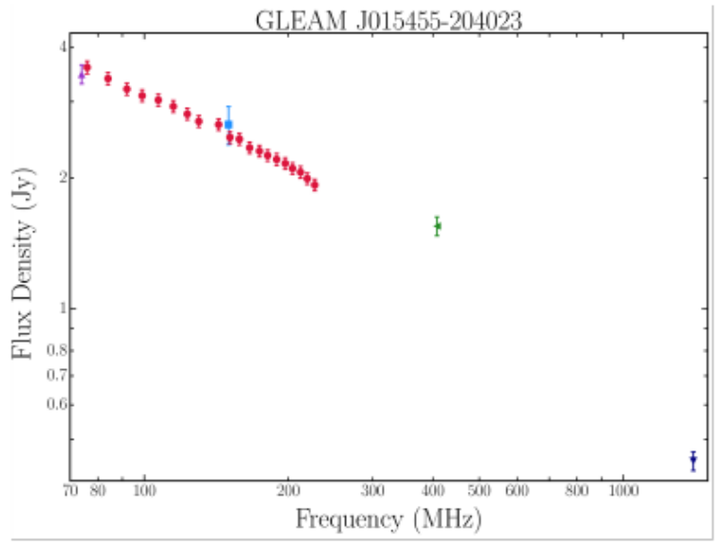








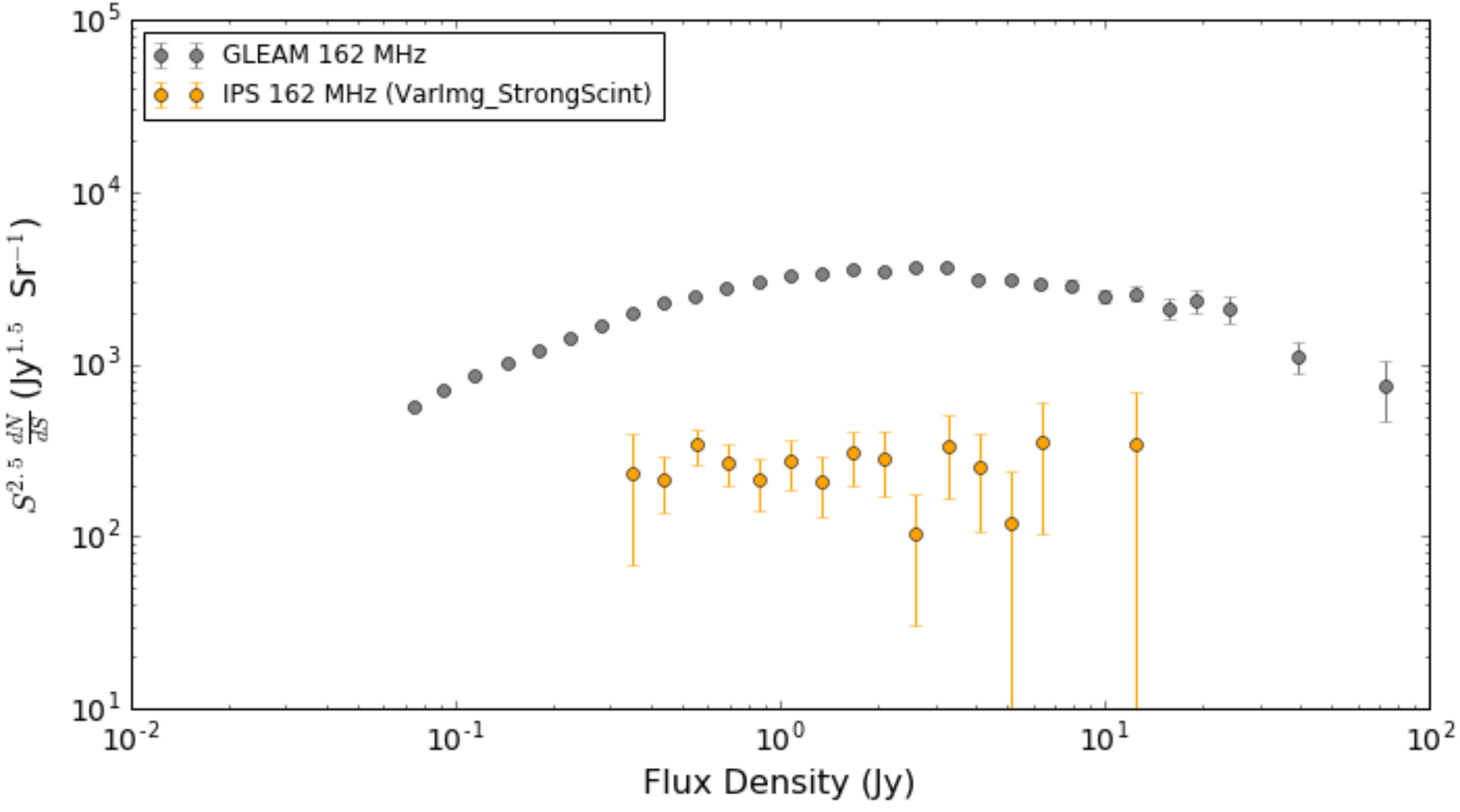




SEDs Credit: Joe Callingham

Compact source counts

Does the compact population evolve differently?

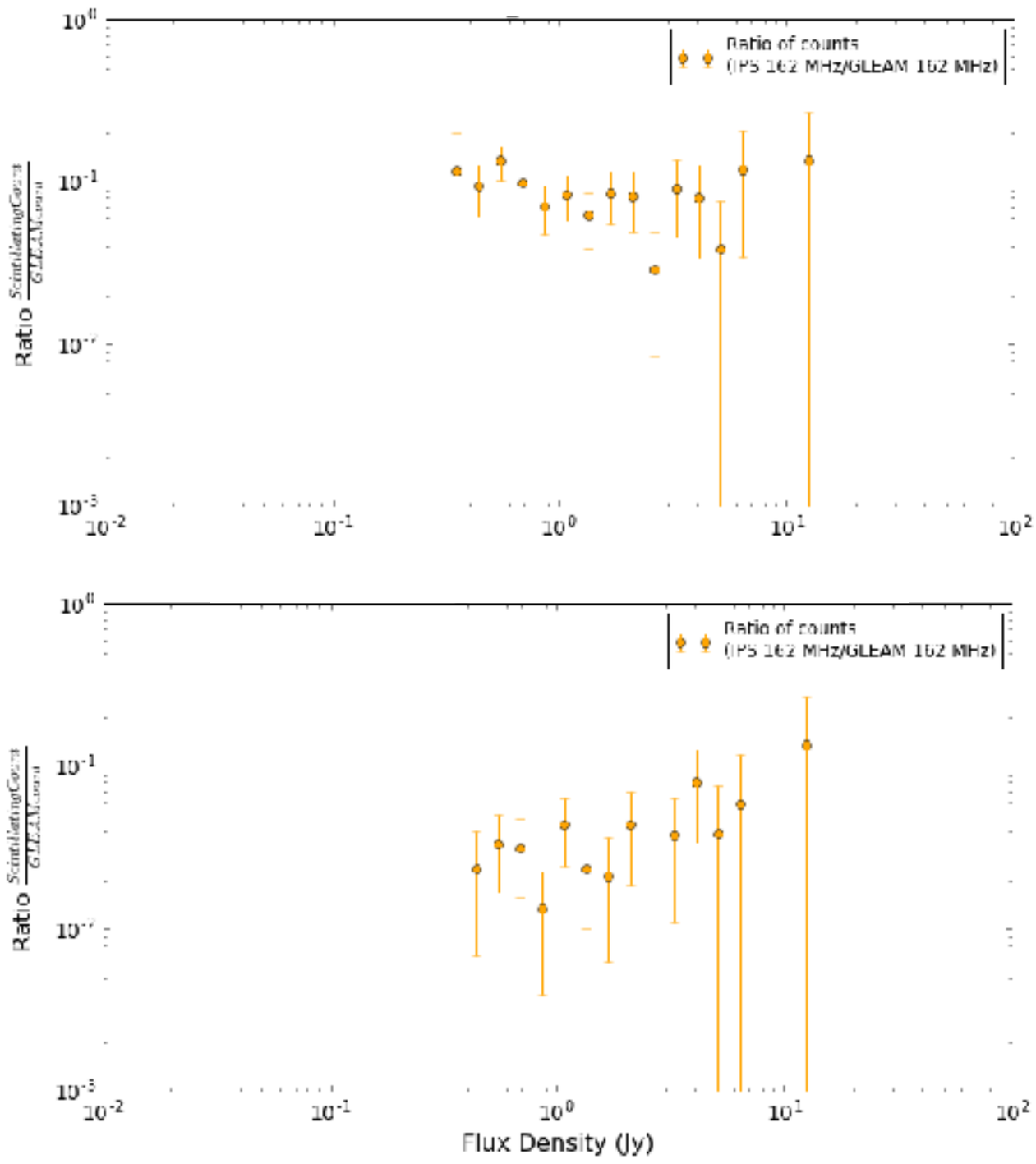


Source counts II

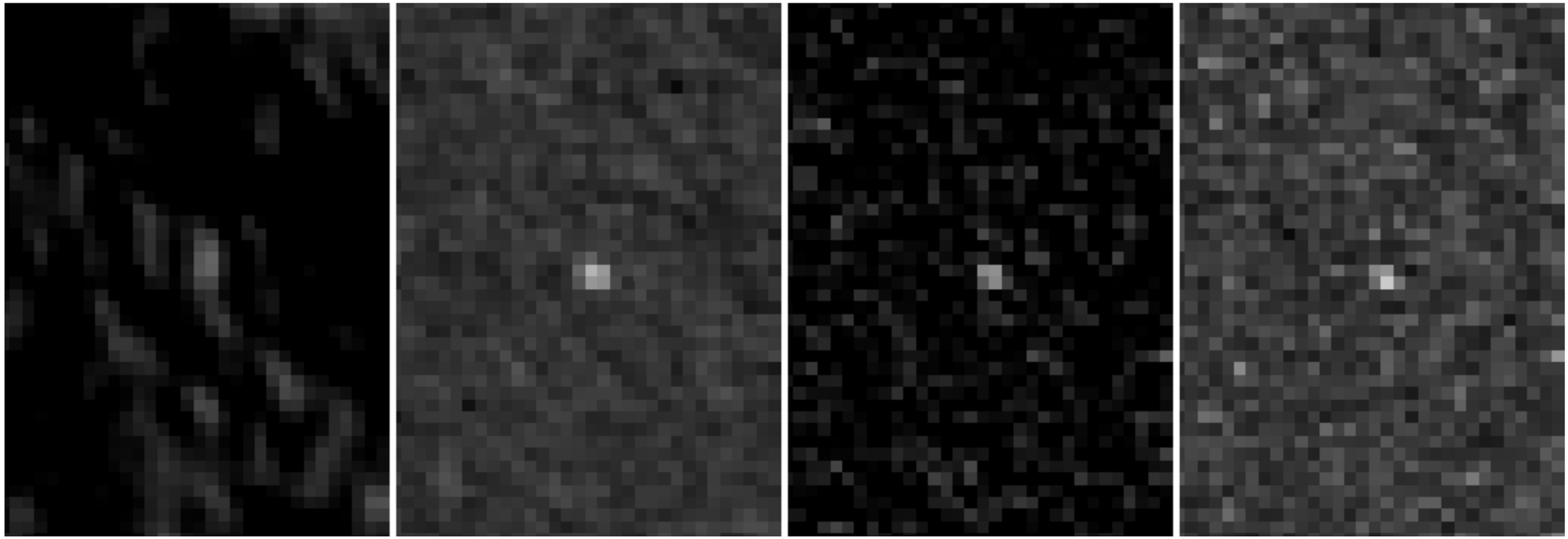
Fraction of total radio counts
that are
compact quasars

versus

Fraction of sources
that are
(compact) peaked spectrum



Oddballs: e.g. MSP J0034-0534



Continuum	RMS	Skew	Kurtosis
2.5σ	17σ		

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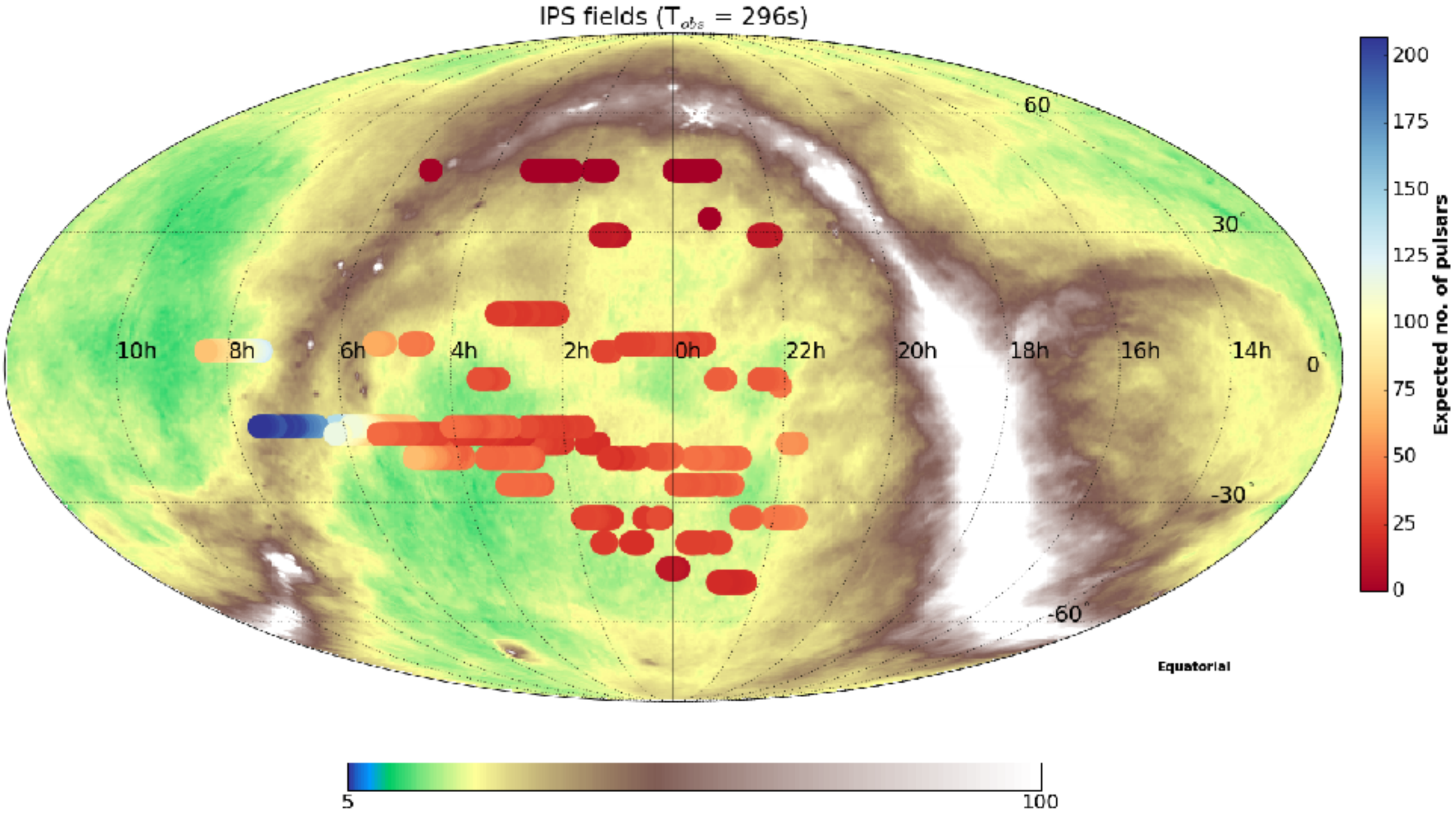
IPS fields



Conclusions

- Low-frequency VLBI almost as easy as spotting twinkling stars
  - Typically probes structure <0.3”
  - Like adding 400 km baselines to SKA_LOW

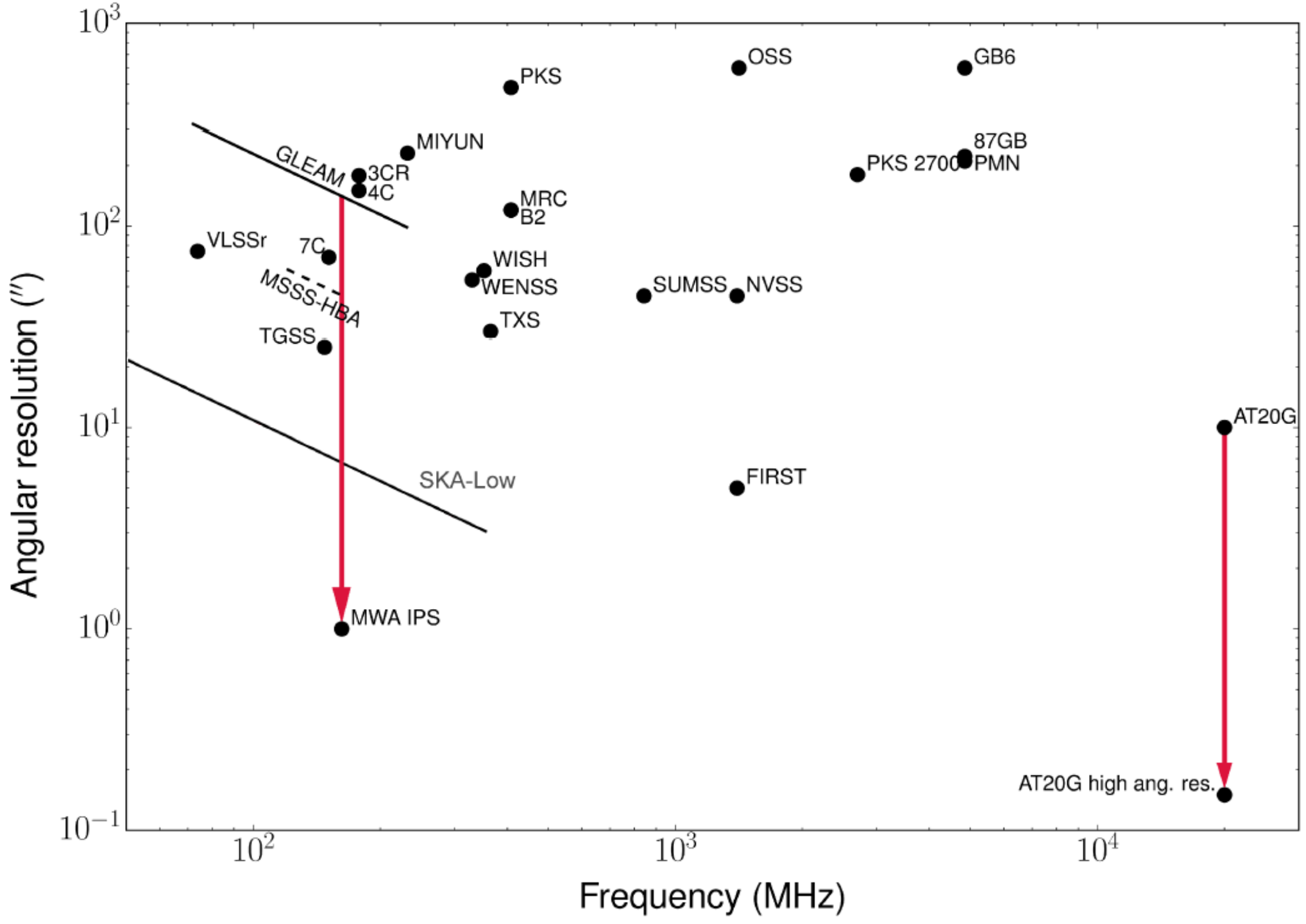
- Peaked spectrum sources all compact

- Sources that are compact at higher frequency (AT20G or Fermi) a poor predictor of low-frequency compactness

Further details

Morgan et al. 2018, *MNRAS*, **473**, 2965
Chhetri et al. *MNRAS*, in press arXiv:1711.00393

Surveys


Angular resolution (″)
Frequency (MHz)
10^3
10^2
10^1
10^0
10^{-1}
10^2
10^3
10^4
PKS
OSS
GB6
MIYUN
87GB
PKS 2700
PMN
GLEAM
3CR
4C
MRC
B2
VLSSr
7C
WISH
WENSS
SUMSS
NVSS
MSSS-HBA
TXS
TGSS
AT20G
SKA-Low
FIRST
MWA IPS
AT20G high ang. res.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